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Electric Light & Power

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Veil of uncertainty lifted at HL&P's South Texas project

Don Minner
Assistant Editor

WASHINGTON, D.C.—Houston Lighting & Power's (HL&P) South Texas nuclear project has received a preliminary stamp of approval from the Nuclear Regulatory Commission's Atomic Safety and Licensing Board (ASLB).

In its March report, the board said, "We perceive this project as one which, although in trouble at an earlier date, has now likely 'turned the corner'."

HL&P's Manager of Nuclear Information Don Beeth said that the ASLB report "has lifted a cloud that has hung over the project for the last several years."

Beeth said the South Texas Project (STP) is now "a shining light in the nuclear industry."

In 1980, the NRC's Office of Inspection and Enforcement released a report citing 22 non-compliances in HL&P's construction practices at the project site. The NRC also said that substantial deficiencies existed in the utility's quality assurance and quality control (QA/QC) programs. HL&P was hit with a $100,000 fine and an or-

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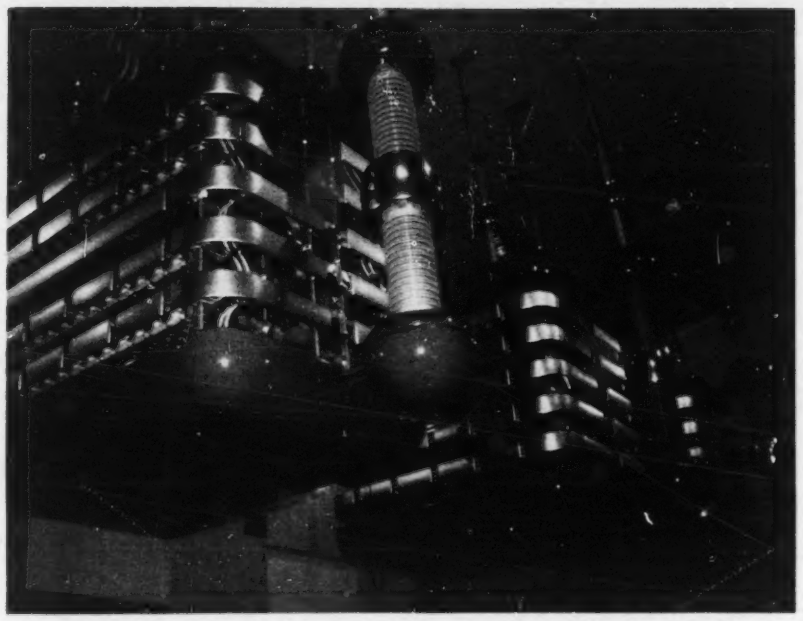

Hanging thyristor valves change a-c to d-c

High voltage direct current transmission is presently the subject of new interest and activity, as utilities contemplate or construct new projects or recondition older ones. Here, three twin valves hang from the ceiling of one d-c converter facility of the Pacific Intertie upgrade being built by ASEA. A second, adjacent building houses three additional twin valves, raising the capacity of the intertie from 1,600 to 2,000 MW. Valve parameters are 2,000 amperes at 100 kiloVolts. An array of series-connected thyristors are inside each of the three valve housings. The new design hangs the valves from the ceiling in order to more fully insulate against seismic shock. Now in the final stages of installation, valve commissioning is expected in early 1985. A Special Report, which includes a look at why HVDC is again becoming popular, begins on page 35.

Policy issues raised in EPA rule proposal on particulates

WASHINGTON, D.C.—Fundamental issues concerning how the Environmental Protection Agency sets air and water quality standards are being raised as part of the agency's recent move to promulgate new regulations for particulate matter.

Particulate matter is the general term for the substances consisting largely of dust, dirt and smoke.

EPA has proposed major revisions in the national clean air standards for particulate matter, changing the focus from larger total particles to smaller, inhalable particles that are more damaging to human health.

But the agency argues that although available evidence clearly supports continuing the regulation of particulate matter, selecting a specific quantitative standard that provides an adequate margin of safety involves uncertainties so large that the entire regulation-setting process may have to be revised in order to accommodate them.

"There are several aspects of this [regulatory-making] process that are especially troubling to me," EPA Administrator William D. Ruckelshaus said at a press briefing the day the agency announced its plan to change

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N.J. commission blasts EPRI foreign research award

PSE&G is required to escrow entire cost of contract

Dan Utroska
Associate Editor

NEWARK, N.J.—Outraged that the Electric Power Research Institute had awarded a $5.7 million research contract to a foreign firm at the expense of New Jersey and other American companies, the state's Board of Public Utilities (BPU) has disallowed the full cost of the contract in annual expenses by Public Service Electric & Gas Company. There were indications at press time, however, that the BPU might relax its stance.

Specifically, the board prohibited company use of money collected from ratepayers for PSE&G membership in EPRI up to the full $5.7 million value of the research contract.

The board said its ruling was based on its finding that the research contract to Sulzer Brothers, the Swiss pump manufacturer, had not been awarded fairly and would undermine the sales position of U.S. manufacturers.

Contract for development

The contract was for the development of an improved design for boiler feed pumps for large coal-fired and oil-fired electricity plants.

An EPRI spokesman, in a telephone interview with *EL&P*, refuted the charges levelled by the New Jersey board.

In its March 16 decision, the board said it would allow Public Service to collect its full annual EPRI membership payment of $6.3 million from ratepayers, but $5.7 million of this—the full cost of the Sulzer contract—would have to be held in escrow for possible use in funding a pump research project proposed by American pump manufacturers.

The board's ruling places Public Service in an untenable position. The utility, a long-time supporter of EPRI, now either has to fund the research of American pump manufacturers and drop out of EPRI, or alternatively, fund both research efforts and collect only once from ratepayers.

No double payment

"We will not continue to pay EPRI and fund this payment of $5.7 million, that is clear," said PSE&G attorney Frank Delany.

At press time in mid-April there did appear to be some room for maneuvering, however, and even the possibility of a negotiated settlement, as the board had not yet issued a formal order on the matter as it had promised to do nearly a month earlier.

In addition, John Ruiz, a confidential aide to New Jersey board commissioner Edward H. Hynes, said that an internally-generated motion to reconsider the ruling was presently before the board.

"The board is confident that EPRI is responding to its concerns," Ruiz told *EL&P*. "What I fully expect to happen...is that the board will treat EPRI contributions as it has always treated them: as expenses that can be recovered in rates charged to customers."

The EPRI spokesman confirmed that he believed the issue would be settled harmoniously.

Agency action is unprecedented

Yet this optimistic and amicable characterization of how the dispute might ultimately be resolved, contrasted strikingly with the more acrimonious language used by the New Jersey board in announcing its disallowance actions.

The board said then that "EPRI relied too extensively on the subjective judgments of its staff, in decisions on research contracts, limiting the ability of the EPRI board to assure fairness to all bidders in contract awards...."

The New Jersey Board of Public Utilities further charged that the Swiss contract would give Sulzer Brothers an "unwarranted advantage" in future sales in the U.S. market for this type of pump.

According to BPU commissioner Hynes, a subsequent agency investigation reportedly revealed that an EPRI manager visited the Swiss company while contract bids were being evaluated, without similar visits to other bidders, thereby appearing to favor Sulzer Brothers.

EPRI refutes BPU allegations

Regarding the charge that EPRI was too subjective in decisions regarding the awarding of research contracts, institute spokesman David Saxe said a host of review processes were in place at EPRI and that they function well to critique proposed contracts.

"We think our process for evaluating proposals in the research and development field is just about as sophisticated as you can get," Saxe said.

Acknowledging that there was no way to totally eliminate subjective judgments in reviewing contract proposals, Saxe reported that a number of outside consultants as well as EPRI's own industry advisory group reviewed the Sulzer proposal before making the award.

Staffed by numerous outside industry experts that have no direct tie with the institute, EPRI's advisory group has been put together as one independent check of proposed research contracts. At least four subcommittees under this advisory group reviewed the Sulzer contract before it was awarded, Saxe said.

Ultimately, the outside consultants, reviewers of the advisory

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Foreign Power Briefs

• **A Swedish research study**, currently in progress, says a system of differential electricity pricing that allows prices to be varied from moment to moment in line with changing generating costs would result in enormous savings of imported oil for most developed countries. At the same time, pointed out the study's authors, the system could reduce costs for both producers and consumers of electricity. The study is being carried out at Linköping University in Sweden and the results are being assessed by the state-owned research and development company.

• **Turkey's electric utility** has a new 400-kV power line spanning the Bosphorous River. Siemens AG built the line for Turkiye Elektrik Kurumu in just 15 months. The line links customers around Istanbul with hydroelectric and lignite-fired plants in central and eastern Turkey.

• **Hydro-Quebec** has agreed to sell 150,000-kW of power over a 10-year period to the state of Vermont. Gov. Richard Snelling said the state will begin receiving the electricity in July 1985. Snelling said the price of the power will be 3.3 cents a kilowatthour, rising to 4.0 cents by the end of the first five years. The price for the second five years will depend on the price of coal and oil. Before the deal can be completed, a substation must be built in northern Vermont. Snelling said that if Vermont's electric utilities don't pay for the construction of the substation, he will ask the state legislature to create a state power authority to build the substation.

• **The Italian National Committee** for Research and Development in Nuclear and Alternative Energies (ENEA) said it has placed an order with Westinghouse Electric Corp., for the nuclear industry's first advanced engineering simulator. It will be used to evaluate nuclear power plant design and operation. ENEA said it will install the equipment in its Rome headquarters. Initially, ENEA will use the simulator to assist in the design of the Italian pressurized water reactor. Westinghouse said the simulator allows nuclear plant engineers and executives to analyze overall plant behavior quickly, without requiring detailed knowledge of the control room operation.

• **European Community (EC)** coal imports from the United States will increase slightly in 1984 to 25.1 million tons, compared to last year's 24.6 million tons, said the EC Commission. The group said that coal shipments from third world countries also are expected to be higher in 1984. The EC Commission reports that total imports should rise from 1983's 62 million tons to 63.2 million tons this year.

• **Ontario Hydro** said it has recommended to its board of directors that all of the pressure tubes in the two-unit Pickering nuclear plant be replaced at an estimated cost of $720 million (Canadian), including fuel replacement. Inspections have shown that the metal alloy is becoming brittle, said the utility. The units will not be restarted until the retubing is completed, sometime before 1987. Pickering-2 has been shut down since one of the tubes ruptured last August. Unit-1 has been down since November for tube inspection.

• **Saudi Consolidated Electric Company** and General Electric have signed two contracts totalling $61.8 million for a gas turbine turnkey addition to an existing diesel power station in Abha. GE said the first contract includes three GE heavy-duty gas turbines, which will provide a combined output of 150 MW. The second contract, valued at $12.4 million, is for a 132-kV substation to be built at the Abha site.

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Garbage power gains in popularity with new projects being announced and new suppliers entering the marketplace.**G** 23

Carolina Power & Light is demonstrating the effectiveness of distribution automation systems.**T/D** 31

The use of high voltage direct current bulk power transfer is again receiving renewed attention by utility power system planners. A look at why this is happening and an exploration of a new, emerging problem of system harmonics is the focus of a Special Report. 35

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EL&P readers whose responsibilities include both Generation and Transmission/Distribution receive both technology sections. Other readers receive the technology section that applies to their respective area of responsibility. The Generation edition is indicated by a single dot (•) in the upper right corner of page 1; the T/D edition carries two dots (••). All readers receive EL&P's industry news section.

South Texas project . . . from page 1

der to show why construction on the project should be allowed to continue.

Two local intervenor groups had requested a hearing on the show cause order, but it was denied by the commission. Instead, the NRC agreed to hold early hearings on the QA/QC issues. Those hearings were held between May 1981 and June 1982. Then, on Sept. 24, 1981, the utility fired its architect-engineer and construction manager, Brown & Root (B&R). Bechtel Power Corporation was hired to replace B&R, while Ebasco became constructor on the project. To the welcome relief of the utility, the ASLB issued its findings on the initial hearings in March.

Two more phases of hearings still need to be held before final approval is given to the $5.5 billion twin-reactor 2,500 MW South Texas project, but HL&P's Beeth said the utility feels those will be "much less complicated" than the first ones.

Another hearing will be held to discuss a report on B&R engineering that was done at the request of the utility by Quadrex Corporation. The third hearing will address any remaining issues. Those hearings could be held as early as the fall, said the HL&P spokesman.

Project on schedule

Beeth said that approximately 6,000 craftsmen are working 20 hours a day, 7-days a week in order to have Unit-1 ready for fuel loading by 1987. "We're right on schedule to a tenth of a percent," enthused Beeth.

As of mid-April, the project was over 50 percent complete, according to the utility. Beeth said Unit-1 was 56 percent complete and Unit-2 was 31 percent finished.

Beeth singled out the work of Bechtel and Ebasco for keeping the project in such good shape. "The cooperation between them is a marvel to behold," he said. "You'd think they were all working in the same company."

In its report, the ASLB said, "...it is our opinion that HL&P is not now deficient in character and has not demonstrated character deficiencies which would warrant denial of operating licenses."

Although HL&P's competence was questionable at the time of the NRC investigation, said the board, it now appears to have substantially improved.

HL&P's problems

The board said HL&P's problems with the project "were traceable, in our opinion, not to character defects on the part of HL&P but, rather, to deficiencies in two key ingredients of competence: experience with respect to design and construction of large nuclear facilities such as STP on the part of both HL&P and B&R, and long lines of communication which resulted in HL&P's inexperienced management failing to receive the information it required to operate a successful QA/QC program."

The board went on to say, "We now have reasonable assurance that structures which are complete and work which has been performed comply with applicable regulatory requirements, and that future work activities (including implementation of the QA/QC program for construction) will be carried out satisfactorily."

"We feel the project is in good shape," assured Beeth. "We will still have violations, but they will be few, they won't recur and we will correct them with vigor."

The ASLB report also addressed several of the charges made by the intervenor groups concerning concrete and welding at the project. The board said there is "reasonable assurance" that the concrete work and the backfill at the project site are in conformity with construction permits and NRC regulations.

As to the welding, the ASLB said, "We find that HL&P is conducting a thorough reevaluation of the STP welding program. This evaluation has resulted in the discovery of significant defects in existing welds and significant improvements in the welding program to prevent recurrence of those defects."

Intervenors recognized

The ASLB recognized the intervenor groups—Citizens for Equitable Utilities, Inc., and Citizens Concerned About Nuclear Power, Inc.—for their efforts in bringing serious QA/QC questions to the attention of the commission.

Said the board, "They (the intervenors) initially raised these issues long before the NRC recognized their significance and for this they are to be commended."

There is no basis, said the ASLB, for concluding that the utility lacks managerial competence and integrity. "HL&P is presently managing, planning and implementing its program for the balance of design and construction of STP, including its QA program," said the ASLB, "in a manner which provides reasonable assurance that future design and construction work at STP will be in conformity with the construction permits, the Atomic Energy Act, as amended, and the rules and regulations of the commission."

Acid rain plan misunderstood, says EPA

WASHINGTON—The Reagan administration's recently announced policy on acid rain has been misunderstood, according to Charles Elkins, director of the non-research portion of the acid rain program at the Environmental Protection Agency.

Noting that the policy called for greater funding for research, Elkins told the recent Energy Technology Conference meeting here, "Those who think we're in favor of no control are incorrect. We're right in the middle."

Elkins said that President Reagan asked William Ruckleshaus to "focus" on acid rain when he appointed him to head EPA last year, and that's what Ruckleshaus is continuing to do. The administration's "intense" review of the state of knowledge on acid showed, according to Elkins that, "Researchers found that what we know today is less than what we thought we knew two years ago."

Elkins said that while researchers know there is acid lake damage occurring downwind from regions that emit sulfur dioxide from power plants they don't know how extensive the damage is and they don't know what effect a control program would have on the lakes. Another big question is the effect of acid deposition on forests, a big problem in Germany that has not occurred here yet. "Are we just a few years behind?" Elkins asked.

The official said that a survey of lakes and forests now being conducted will show the extent of current damage and how fast the "ecological clock" is turning.

High Voltage d-c transmission plans are re-energized; harmonics issues emerge

Dan Utroska
Associate Editor

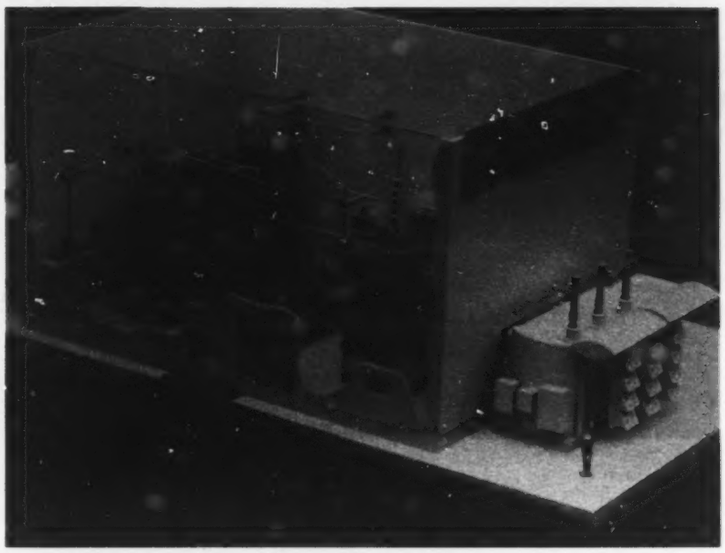
Thomas Edison would be happy. The idea of direct current power networks is once again being seriously promoted by power system planners.

The venerable old researcher, who initially conceived of a vast electrical network spanning the United States, envisioned that it would be constituted of direct current components because of the inherent advantages in this type of power generation and transmission.

But Edison lost out to the alternating current advocates, principally on the basis that a-c voltages could more easily be stepped up or down for transmission and distribution.

Today, a confluence of new social, economic, and technical developments again has brought direct current transmission to the forefront of contemporary power system analyses. Principally conceived as a constant-voltage link in an a-c network, d-c offers the promise of otherwise unobtainable economical energy transfer, enhanced power control, and greater system reliability.

The recent surge in d-c system orders is occurring against a backdrop of a more general focus of attention on electricity transport mechanisms. This focus stems to large degree from increasing financial, regulatory and demand uncertainties that make new power plants more difficult to construct. The growing disinclination of electric utilities to build new generating plants, combined with very large capacity excesses in many parts of the U.S. and in Canada, naturally has turned analytical and engineering heads toward new transmission regimes, in an effort to equalize regional power disparities.



Artist's rendering shows the main components of a General Electric high voltage d-c converter station. Solid state thyristor valves transform a-c power to d-c, while the converter transformers provide phase shifts required for valve operation and maintain valve voltages.

"Basically, the industry is facing the recognition that the emphasis in power systems has shifted from generation to transmission and distribution," notes Walter Ros of General Electric Company. "The public utility commissions are doing the same thing."

Even though the most recent survey by the National Electrical Manufacturing Association shows that electric utilities again have decreased their estimates of new transmission lines to be added through 1992 (*EL&P*, April), analysts looking at high voltage direct current (HVDC) potential see measurable growth in new facilities just over the horizon.

Economical energy transfer

One source of these new T-line facilities is the possible benefits from economical energy transfer. For example, in late March Southwestern Public Service Company and Colorado-Ute Electric Association Inc., announced they had entered into a joint agreement to construct a $19 million, 125 kiloVolt HVDC line between SPS facilities near Guymon, Oklahoma and Colorado-Ute facilities at Violas, Colorado.

SPS is a summer peaking utility, while Colorado-Ute is a winter peaking generation and transmission cooperative. "Under our agreement, Colorado-Ute will generate some power for our customers during summers," said Bert Ballengee, SPS president and chief operating officer. "We'll generate some power for their customers during winters. That will hold down costs for both utilities."

In announcing the joint agreement Ballengee said it would have been technically impossible for the two utilities to exchange power directly without the direct-current facility. This is because construction of the system provided for the possibility of energy transfer between two asynchronous systems, or systems that have different transmission characteristics. In this case the line crosses the boundary between the Western and Eastern interconnnection (see map).

According to General Electric Company's Dr. Frederick J. Ellert, there is great potential for this kind of power exchange. Electric energy, he says, could be transferred very economically from those areas of the country where surplus low-cost generation exists, to other parts where expensive oil and gas are being burned.

Ellert calculates that currently about 135 gigawatts (GW) of electric power is being fueled by oil and gas in the U.S. This is produced by plants

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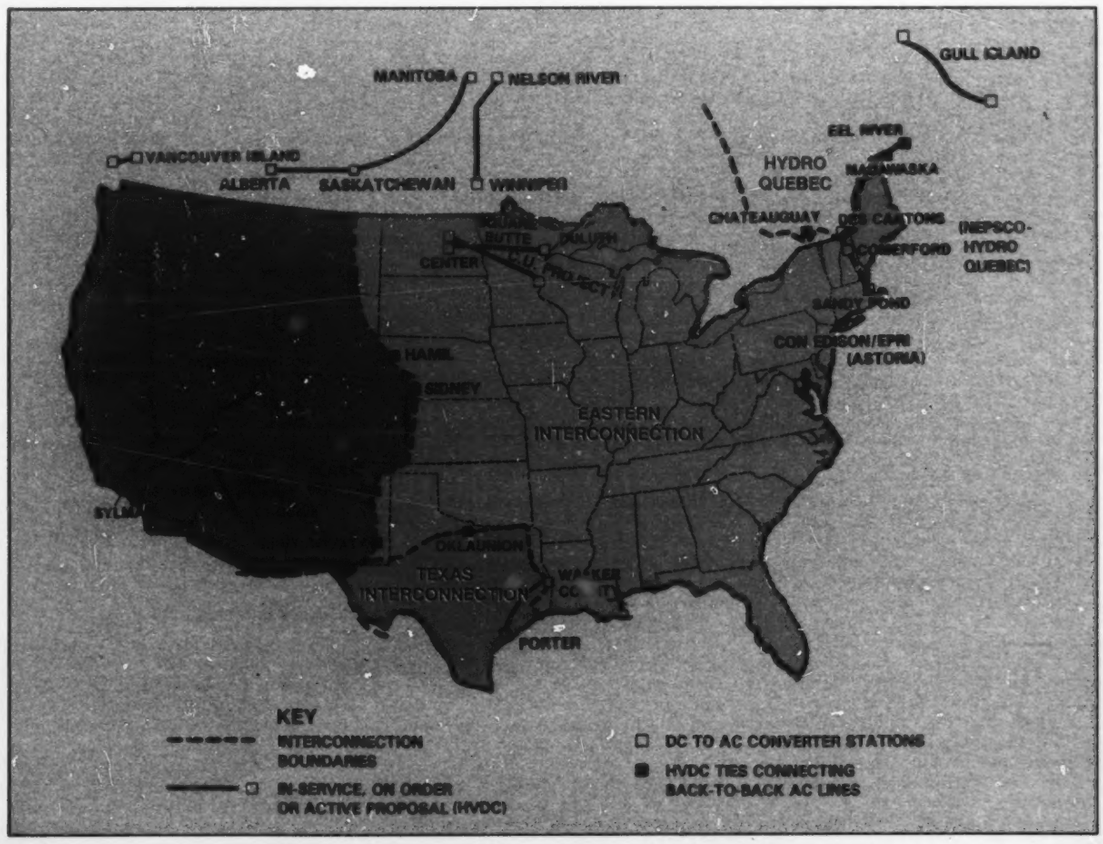
Project	Rating, MW
*Salt River	1800-2200
Intermountain	1600
Hydro Quebec-New England Electric (Canada-United States)	690-2000
C.U. Project	1000
Walker County	520-1040
Square Butte	500
Pacific Intertie	400
Oklaunion	200
Eddy County	200
Miles City	200
*Sidney	200
*Blackwater	200
Hamil	100
Astoria	100-400
Nelson River	1620-2000
*Manitoba-Saskatchewan-Alberta	1800
Chateauguay	1000
*Gull Island	800
Vancouver Island	670
Madawaska	350
Eel River	320
*Japan	15,000
Brazil (Itaipu)	6000
USSR (Ekibastuz)	6000
*China	2000
England-France	2000
*Malaysia	1200
USSR-Finland	1000
*Mexico	900-1600
*Philippines	800
*India	500-1000
Austria	500
*Bulgaria-Greece	300
Corsica Tap (Sardinia-Italy)	50



'When the line becomes long enough,...then there is a straightforward justification for the use of direct current.'

High voltage direct current . . . from page 35

principally located along the coast in New England, and the mid-Atlantic states, Florida, Louisiana, Texas, Oklahoma, and California. In a GE-conducted study, these plants were found to have an average annual capacity factor of about 45 percent and it was estimated that about 30 percent (or about 40 GW) of this oil and gas-fired generation could be displaced by lower cost fuels.

"The annual saving in the United States would exceed $4 billion and would pay back the cost of the additional transmission required in less than two years," Ellert said. "Due to the long distances involved, more than half of this transmission could be in the form of HVDC transmission."

But coal-fired electricity need not always displace oil and gas capacity in order to achieve economical energy transport savings. Hydro Quebec has enormous hydropower resources that are already built and to the extent that this power is excessive in Canada, its incremental cost per kilowatt-hour approaches zero. Thus, the use of HVDC to interconnect that Canadian utility with the Northeastern United States promises relatively inexpensive power to that region, even after the cost of the new T-line is calculated and amortized.

HVDC systems need not have transmission lines associated with them, but can be used exclusively to link asynchronous a-c systems. As the accompanying map shows, the U.S. is divided into three major interconnections; the Eastern interconnection, the Western interconnection, and the Texas interconnection. By installing d-c links, two nonsynchronous a-c systems can be interconnected for the purposes of power transport.

HVDC growth estimates

Overall, when reasons in addition to economical energy transfer are considered as possible stimulants for new HVDC construction, it is estimated that the potential market worldwide is about 15 to 20 GW over the next five to 10 years. As can be determined from the accompanying chart, there is currently about 12 GW of HVDC capacity now either in construction or operation in North America.

GE forecasts that HVDC systems are likely to grow at about 15 percent per year from now through 1990. ASEA, the other major supplier of HVDC systems, estimates that over the next five years, average annual HVDC system increases in the U.S. will be about 500 to 1000 MW.

Certain recent technical and economic developments associated with high voltage d-c systems do appear to offer the possibility of vigorous growth in the near and mid term. The actual construction of a number of new HVDC systems around the world give added support to this view.

But opposing these developments are concerns that worry HVDC advocates and that pose serious obstacles to the rapid growth of the technology that proponents foresee. Clearly, a tension has been set up among these forces and only the evolutionary pace of future technical advances and regulatory innovation will decide the outcome.

Perhaps the two major elements working to support the HVDC growth are the differences that now exist across the U.S. in electric generating capacity and the measurable improvements that have been made in high power d-c converters and solid state controls. The latter development offers HVDC systems of substantially enhanced reliability, as contrasted with earlier systems. Both of these tend to make HVDC systems appear attractive.

D-C converters much improved

Direct current converters are, simply, those devices that transform a-c current into d-c. Specifically, they are rectifiers that transmission engineers refer to as valves.

Today, modern thyristor valves have replaced the older mercury arc valves. Mercury arc valves have been installed and are operating in 11 of the 12 HVDC systems commissioned between 1954 and 1975 and are responsible for whatever measure of success current HVDC systems have enjoyed.

ASEA introduced the first HVDC system using thyristor valves in 1970; General Electric offered its system commercially two years later.

State-of-the-art thyristors are now larger in diameter than their predecessors and thus have increased power handling capability. Present-day thyristors have test voltages of up to 5 kV. Thus a single bridge made of six, 100-mm diameter thyristors can deliver 5 MW of continuous rated d-c power.

The increase to 100 mm diameters today from the approximately 25 mm diameters in the mid 1960s, means that currently fewer thyristors are required for a given power rating, and most engineers believe that further improvements are possible.

In addition, total losses experienced by a d-c converter station reportedly have been reduced to about one percent of the d-c power rating, with about one-third of the losses attributable to the water-cooled thyristor valves.

Further, HVDC growth advocates point to the enhanced reliability of newer, more recently designed systems. In the event of a fault on one electrical pole (plus or minus) of a d-c system, the earth can be used to carry the current of the functioning pole.

Energy availability is one measure of reliability of HVDC systems. According to General Electric, energy availability, on an annual basis, has been over 98 percent for its equipment used in HVDC systems. ASEA reports equivalent figures.

Elegant controllability

One of the more elegant features of HVDC is its preeminent controllability. With such a system, current or power can be defined and maintained in order to improve the dynamic performance of related a-c systems.

ASEA's Power Systems Center director Dr. Willis F. Long points out that d-c systems can respond to power changes extremely rapidly. For example, he notes that acceptance tests on the Pacific Intertie (see map) verified that full power reversal—from 1440 MW North-to-South to 1440 MW South-to-North—could be achieved in ⅓ of a second.

Long raised the possibility that, with the development of efficient d-c breakers, d-c networks could be set up, thereby expanding the use of HVDC beyond present day point-to-point applications.

A good example of the limitations of d-c transmission without d-c circuit breakers is the Pacific Intertie line. It has only two terminals: one at The Dalles, Oregon, and the other at Los Angeles. Had HVDC breakers been commercially available when the intertie was built, branch lines could have been extended to San Francisco, Salt Lake City, and Phoenix. But without such breakers to isolate faults on the branch lines, such "networking" becomes impractical.

High voltage direct current breakers have been difficult to develop. Unlike alternating currents, high voltage direct currents flow in one direction only. Attempts to interrupt the flow by placing a gap in the conductor merely causes the current to arc over the gap. At 500 kV, for example, even a gap of 50 ft is insufficient to stop the current flow; it will continue to stream, twisting in the process like lightning.

Recent developments, however, suggest that successful breakers are at hand. The ability to control power flow with the precision that HVDC circuit breakers would provide has wide applicability in power disturbance situations (such as the infamous New York blackouts), as well as in routine system maintenance.

Dr. Jerome Meisel of Wayne State University has looked into some possible applications. In a recent study conducted for the Department of Energy, Meisel analyzed a transmission emergency situation similar to the 1977 New York blackout.

Here, a large metropolitan area that imports nearly one-half of its power suffers a power generation emergency. Although numerous surrounding utility service areas are connected and have excess capacity to share with the troubled area, a-c electricity transport to the affected area is not directly controllable. Efforts to provide the downed area with additional generation under an a-c regime, inevitably overload incoming a-c tie lines, thereby tripping them out of service.

To solve this reliability problem, it is proposed that a single, bi-polar d-c "transmission ring" be installed circumferentially around this metropolitan area, interconnecting the rescue area tie lines at the point where each of these originates. Such a ring would have d-c converters located at the external tie-line buses. With proper controls, Meisel calculates that this ring could readily balance electricity flows on the tie-lines from any of the rescue areas surrounding the region in trouble.

Such electricity transport, he maintains, would therefore be done without tie-line overloads, as would certainly be the case if the ring were constructed using a-c transmission.

Economics still evolving

The evolution of semi-conductor technology that has introduced the thyristor converter and has correspondingly brought down the costs of HVDC has coincided with a national economy of abiding volatility. These circumstances have brought HVDC not only into direct competition with a-c facilities in many applications, but with new electricity generating facilities as well.

"When the line becomes long enough, the savings in a d-c transmission line equal or exceed the cost of the converter terminals," says GE's Jack Fink. "Then there is a straightforward justification for the use of direct current."

Presently, as a rough approximation, as the "break-even" distance for HVDC overhead transmission approaches 300 miles, it is generally considered economically prudent to considered d-c. For underground or underwater cable applications, d-c tend to be economical for lengths of about 20 to 30 miles, proponents say.

Yet, the use of d-c for asynchronous ties, installed back-to-back, is not related to conductor length and reportedly can be economically justified on the basis of the power transformation and linking services it performs. Dr. Fink notes that the average length to date of GE HVDC projects is about 45 miles.

But HVDC economics, as attractive as they may be for certain, clearly-defined instances of point-to-point facility construction, are more uncertain in other instances. The cost of the converter terminals, though reduced from former times, is still high and may preclude utilities from opting for direct current lines in many instances.

As GE's Fink notes, capital expenditures are increasingly difficult to justify in the electric utility industry. "This is an industry beset with priorities as to where to spend money," he says. And an electric company that does decide to build an HVDC line for the purposes of economical energy transfer, has to move quickly and without hindrance in order to secure the benefits it seeks. In many cases utilities with excess capacity can only be expected to offer it for a relatively short time—perhaps up to about 10 years in some cases, less in others. Sooner or later load growth will consume this excess capacity and a utility building a new T-line will have to be sure that the kilowatts eyed are still available when the line is finished.

Innovative financing needed

Compounding this demand/supply matchup, electric utilities may find it difficult to finance large, expensive transmission projects over this relatively short time period. GE's Dr. Ellert notes that under traditional ratemaking schemes, a company would have to amortize its T-line investment over decades, while ratepayers would be the immediate and continuing beneficiaries of inexpensive power importation. Such circumstances, short of other compensating considerations, could provide strong disincentives for utility investment in HVDC. Such circumstances, therefore, argue strongly for innovative ratemaking schemes.

Such schemes are not without precedent, however. The Florida Public Service Commission has, as part of its regulations, an oil back-out cost recovery clause. This rule establishes criteria under which a utility will be granted expedited capital recovery if it can demonstrate that construction of a new generation or transmission facility will pay for itself in oil savings.

In response to this rule, Florida Power & Light is building a 500-kV

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'The sophistication of the American consumer has gotten to the point where he expects more out of the power system than he expected even five years ago.'

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a-c transmission line that will run along the east coast of Florida and interconnect with Georgia Power Company. FP&L has "qualified" construction of one segment of the line under the PSC's new rule by demonstrating that projected oil savings associated with the line would, over a 10-year period, offset the revenue requirement needed to construct the project.

Thus qualified, costs are recoverable through the fuel adjustment clause. If, however, oil savings *more* than offset these revenue requirements, the company is entitled to retain two-thirds of the savings. According to PSC spokesman Bob Trapp, this turns out to be a form of accelerated depreciation and aids the company's cash flow situation.

This innovative regulatory scheme would apply equally to an HVDC line, should this ever be needed in the area. The only requirement is that it pay for itself in oil savings.

While Florida may not be the only state that has an innovative rate scheme to encourage economic energy supply, it surely is one of the very few.

Further, the development of multiterminal HVDC systems has been hampered in part by the present lack of experience with these systems. "Planners are not familiar with the capabilities of these systems," notes Dr. Robert Lasseter of the University of Wisconsin. "No adequate software simulation tools exist, and new concepts of operation of multi-terminal systems different in nature from the concepts used for the operation of point-to-point HVDC systems need further evaluation."

Circuit breaker 'breakthrough'

Also needing further evaluation is the recent development—termed a "major breakthrough" by engineers associated with the project—in the area of d-c breakers announced in mid-March by the Bonneville Power Authority. Without such a breaker, the development of multi-terminal HVDC networks is precluded.

BPA reported that it has completed successful testing of the first HVDC circuit breaker. In its announcement, BPA said the 25-foot-high prototypes of the switch have been built and tested on a fully energized 800 kV segment of the Pacific Intertie.

According to BPA, this achievement was accomplished by applying a "counter voltage" to the HVDC arc formed between the gap in the electrodes. Simultaneously, zinc oxide resistors brought the current to zero, while absorbing a significant part of the energy.

BPA reports that recent advances in metal oxide resistors made this electrical scheme possible.

"The marvelous thing about the two prototype breakers is that they are composed of standard, off-the-shelf components, like a-c circuit breakers, capacitors, and zinc oxide resistors," says Stig Annestrand, BPA's manager of research and development.

This conclusion is confirmed by ASEA's Dr. Long, who was involved in the planning and directing of circuit breaker research for the Department of Energy. He says that this off-the-shelf equipment, assembled in this unique way, makes the d-c circuit breaker readily available for use in HVDC systems.

What is not readily available is a long history of field testing and any demonstrated enthusiasm on the part of electric utilities to experiment with new technologies. "I don't get the feeling the industry is sitting there thinking, 'Let's get something brand new,'" Wayne State's Dr. Meisel said in response to a question on how soon the d-c breaker might be used in HVDC systems.

Harmonic filters effective

Another consideration potentially dampening utility enthusiasm for HVDC systems is the generation of unwanted system harmonics. Harmonics are voltages and currents at frequencies above the standard 60 Hz that characterizes the a-c system in the U.S. Stemming from rectifiers, HVDC converter terminals, and variable speed motor drives, such voltages and currents distort the normal utility sine wave. If severe enough, harmonics can lead to flashovers from insulation degradation and can cause overheating and failure of utility equipment.

Present technology is capable of filtering out these harmonics, researchers say, but the trick is to do it efficiently and in a cost-effective manner. A knowledgeable source at ASEA points out that harmonics are not only generated by d-c conversions but are part of existing a-c systems. Because utilities constructing d-c facilities have to specify technical requirements regarding harmonic filtering, and because these utilities are not always fully knowledgeable about the harmonic content of their a-c systems, often filters are more conservative, and therefore more costly, than they need to be. Consequently, these filters remove even a-c harmonics.

Both GE and ASEA maintain that harmonics themselves have not interferred with the successful operation of HVDC systems.

The Electric Power Research Institute is looking into this question of harmonics and has developed a computer program called HARMFLO for harmonic analysis. Conceptually, a program that models the creation and spread of harmonics can aid the solving of insulation coordination problems as well as addressing concerns in system protection and HVDC filter design and operation.

EPRI claims that its HARMFLO program constitutes a significant improvement over other methods used for harmonic analysis because only power demand and load type need be specified. This means that the harmonic content need not be known before the analysis.

In addition, the program not only calculates the harmonics and how they spread, but how they affect each other.

Even though EPRI is calling the development of this program a "breakthrough," the research organization readily admits HARMFLO's limitations. Since the models used for transmission lines, transformers, motors, generators, and loads are simple, low-frequency models, they are limited to frequency ranges between 60 and 1140 (the 19th harmonic).

There are other limitations as well. Nevertheless, the program is presently usable and accurate, EPRI says, and the research study team is working to improve its efficiency and analytical capabilities.

Harmonic effects increasing

This research is necessary, EPRI maintains, because concern about the effects of harmonics on electric power systems is growing. Such concern is expressed not only over bulk power modes of electricity transport, but over harmonics on subtransmission levels as well.

One of the causes of the increased concern over harmonics has to do with improved network monitoring that has revealed many previously unexplained equipment failures attributable to harmonics.

Another reason is that the sources of harmonics are increasing.

This concern over harmonics, particularly at distribution levels, presents potentially serious problems for electric utilities. These problems range from economic to regulatory to difficulties in consumer relations.

Noting that power system switching is a source of harmonic ripples, Mike Moran of West Texas Utilities observes, "I think everybody is becoming more aware of the switching parameters and the harmonic effects these produce, and this means more technical studies are needed."

Engineers and industry analysts point out that identifying all the varied sources of harmonics and attempting to implement remedial measures could prove difficult and costly. First, a host of consumer appliances (such as the variable speed drill) generate harmonics. Second, as the idea of dispersed generation by non-utility entrepreneurs begins to take hold, the production of electricity by "alternative" generation such as windmills will increase, and this has implications on the quality of line power.

Questions have been raised about these alternative power producers regarding how the quality of their output will be regulated. Should they be free to put out whatever they want? Should they be required to deliver a certain level of quality power? Should the major utility under which these alternative power producers function be required to monitor and possibly clean up the lines? Who is to decide this? How much will it cost?

In addition, there are consumers who, because of technically sensitive applicances like personal computers, desire that power be maintained in a quality state. "The sophistication of the American consumer has gotten to the point where he expects more out of the power system than he expected even five years ago," notes Moran, who is head of the Edison Electric Institute's subtransmission group.

Missouri University professor of electrical engineering Jay D. Morgan concurs. "We are only now beginning to see this as a major problem," he says. He notes that the improvement in the use of electronics, particularly silicon controlled rectifiers, is what potentially threatens to degrade distribution power quality.

Rate treatment foreseen

Dr. Morgan even foresees the possibility that electric utilities, forced to confront this growing menace, would seek rate base treatment for harmonic filtering activities.

In addition, industry organizations such as the Institute of Electrical and Electronics Engineers, in an effort to formulate guidelines for maintaining power quality, may involuntarily lay the base for future regulations in the area.

Bob Bischke of Wisconsin Electric Power Company (WEPCO) has done a lot of work in this area and believes that as consumers experience growing incidents of harmonic interference—such as TV reception distortions—they naturally will expect the local electric company to figure out what is wrong and to fix it.

"This is what will cause utilities to become involved in this," he says.

Bischke notes that although many utilities have special test groups to check out the sources of interference, most utilities are not equipped to do this.

The proliferation of personal computers is what make the problem critical. Better built computers come equipped with uninterruptible power supplies, so that in the event of a power transient or outage, an auxiliary battery power supply automatically kicks in. The computer operator sees no degraded operation.

Customer complaints?

But less expensive PC's do not have such power supplies. Thus, electricity transients or brief outages, which before were met with amiable tolerance by customers, may now be sources of consumer rage.

What makes the problem one of serious concern is the lack of current knowlege about certain aspects of it. Engineers and analysts suspect that there may be harmonic mitigation characteristics inherent in the distribution network. But they have yet to demonstrate this.

"I think we will find that for certain distances and for certain voltages, this will be a non-problem," said Bischke, who is conducting a two year WEPCO study on the issue.

There may be certain classes of customers for whom this is not a problem. Also, for consumers that do experience problems, a simple device may solve it. In addition, once the problem is more clearly identified, it may be easy and inexpensive for appliance manufacturers to add a mitigation component to their products.

But, laments Bischke, "All this is in such infancy, we don't know what to advise manufacturers."

Dr. Narain Hingorani of the Electric Power Research Institute is one who thinks the problem of distribution in line harmonics generally has been overstated. Standards bodies have addressed the generation of harmonics for large installations, Hingorani says, and for smaller systems harmonics simply are not likely to travel very far into the distribution network.

The EPRI researcher says that the distribution line itself has some inherent harmonic filtering capability and thus, although there may be individual situations where a problem exists, it is not likely to become widespread.

In addition, Hingorani notes that appliances themselves are becoming more technologically sophisticated, so that these are less likely to detect harmonics present in the network.

"There is a case here for paying attention," Hingorani concludes, "but not a case for being overly concerned."